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The Airborne Bathymetric Survey (ABS) concept was adopted by the Defense Mapping Agency (DMA) and the Navy in 1985. The ABS system combines two independent sensors, an active lidar and a passive multispectral scanner using GPS satellite data for positioning, into one integrated system. The Naval Oceanographic and Atmospheric Research Laboratory (NOARL) developed the ABS system. The system was flown aboard a Navy RP-3A aircraft. The objective of the developmental effort was to build a system that is capable of rapidly charting coastal bathymetry from an aircraft in a variety of environmental conditions and to provide the software and algorithms necessary to process the data. The laser sounder and the multispectral scanner collect data in swaths beneath the aircraft. At an altitude of 500 meters, the swath width are about 270 and 840 meters, respectively. Since both are optical sensors, their bottom detection capabilities were limited by the water clarity. In relatively clear coastal waters they were able to measure depths down to 3 optical depths.

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ACTIVE/PASSIVE OPTICAL HYDROGRAPHY

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ABSTRACT

The Airborne Bathymetric Survey (ABS) concept was adopted by the Defense Mapping Agency (DMA) and the Navy in 1985.* The ABS system combines two independent sensors, an active lidar and a passive multispectral scanner using GPS satellite data for positioning, into one integrated system. The Naval Oceanic and Atmospheric Research Laboratory (NOARL) developed the ABS system. The system was flown aboard a Navy RP-3A aircraft. The objective of the developmental effort was to build a system that is capable of rapidly charting coastal bathymetry from an aircraft in a variety of environmental conditions and to provide the soft-ware and algorithms necessary to process the data. The laser sounder and the multispectral scanner collect data in swaths beneath the aircraft. At an altitude of 500 meters, the swath width are about 270 and 840 meters, respectively. Since both are optical sensors, their bottom detection capabilities were limited by the water clarity. In relatively clear coastal waters they were able to measure depths down to 3 optical depths.

KEYWORDS: Remote Sensing, Bathymetry, LIDAR, Multispectral, Airborne.

INTRODUCTION

In 1978 DMA conducted a coastal survey requirements study that identified a backlog of more than 200 ship years. Since then, DMA and the Navy have been engaged in a joint effort to improve hydrographic survey capabilities through automation of the data processing and by developing faster data collection techniques. After several years of research and development, the ABS concept was adopted in 1985.

The ABS system shown schematicly in combines two independent sensors into one integrated system. It includes a laser sounder and a multispectral scanner. The objective of the developmental effort was to build a system that was capable of rapidly charting coastal bathymetry from an aircraft in a variety of environmental conditions and to provide the software and algorithms necessary to process the data.

NAVOCEANO estimated that the data collected by the ABS aircraft in 200 survey hours during one year would be equivalent to the data collected by a conventional survey ship in thirteen years. Figure 2 illustrates the relative rates of data collection between the Laser Sounder and ship surveys. This figure shows 4 seconds of data collection for each type of acquisition. In addition to this coverage the NORDA Scanner provides a swath twice as wide as the Laser Sounder. Furthermore, a cost comparison[1] has shown that the aircraft would achieve a cost advantage of five to one, including data processing. It should be recognized, however, that the ABS system was intended to complement, rather than replace, ship survey capabilities, because there are many tasks that ships and sound boats perform that the ABS system cannot.

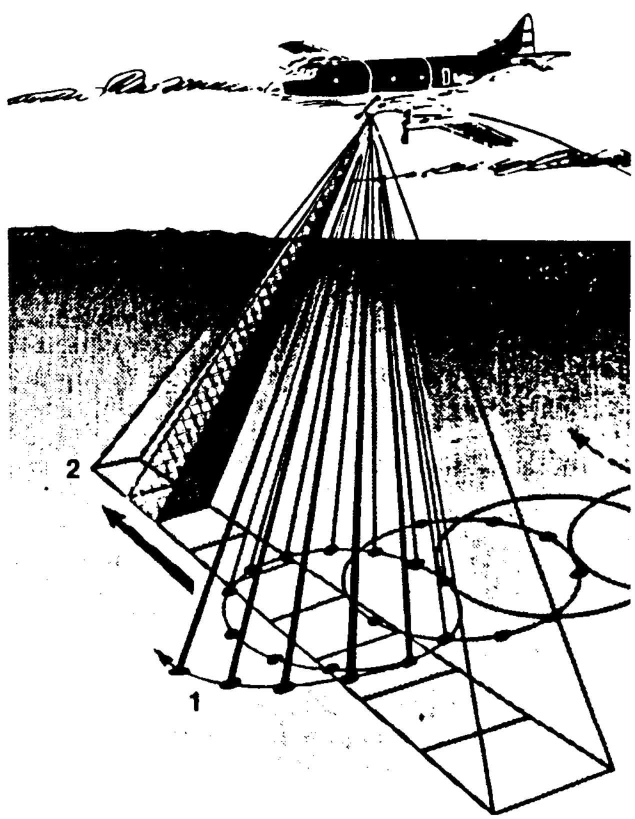

Fig. 1 - AIRBORNE BATHYMETRIC SURVEY SYSTEM.

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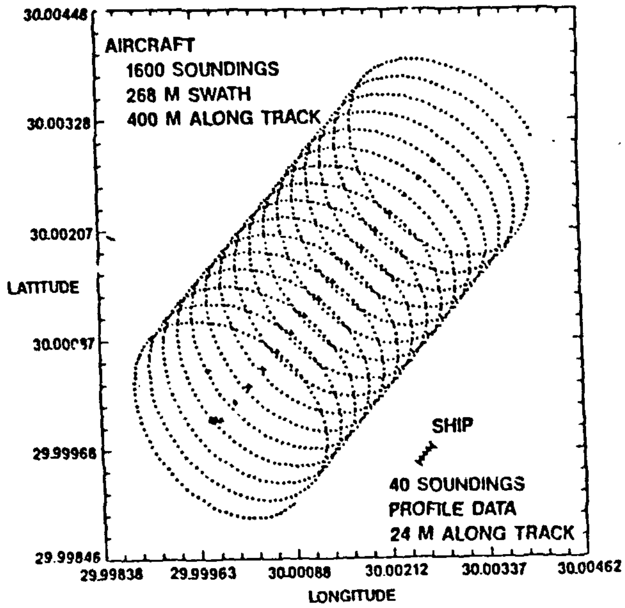

Fig. 2 - COMPARISON OF SHIP AND ABS DATA ACQUSITION RATES.

Both the laser scunder and the multispectral scanner collect data in a swath beneath the aircraft. At an altitude of 500 meters, the swath width was about 270 meters for the laser multispectral scanner. Since both are optical sensors, their bottom detection capabilities is limited by the water clarity. In relatively clear coastal waters (Secchi depth greater than 10 meters) were expected to measure depths down to 30 meters. Also, both systems are effected by sun glint, sea state, and other environmental factors that must be considered in planning airborne survey operations. The Laser Sounder is an active sensor so night survey's can also be employed. At a speed of 220 knots, with no gaps between laser sounding swaths, the ABS aircraft would capable to surveying over 6000 square nautical miles per year (assuming 200 survey flight hours per year). This is the mode in which the ABS aircraft was initially intended to operate, using the laser sounder as the primary sensor with multispectral imagery for detailed analysis of anomalous features and coastlines.

The data collected by the ABS system was recorded on high density digital tapes. Postprocessing of the data was performed at NORAL. The Coastal Secchi Depth Atlas[7] shows that approximately 86% of the world'scoasts have Secchi depths greater than 10 m and are thus potentially surveyable by an ABS type system. Hypsometry data show that approximately two million square nautical miles of the world's oceans are 30 m in depth or less. At this rate it would take 27 years to survey just 10% of this area by aircraft and significantly longer by ship.

OPERATIONAL SCENARIO

The originally intended scenario had the ABS NORDA Scanner and the ABS Laser Sounder operating simultaneously on a P-3 aircraft from an altitude of 500 m. At this altitude the ABS Laser Sounder would provide accurate depth measurements over a 270 m swath, while the ABS NORDA Scanner was providing 100% coverage over a 580 m wide swath. The P-3 would be flown along tracks parallel to the beach with an overlap of approximately 20% in the swath of the ABS NORDA Scanner. These tracks would continue offshore until the depth exceeds 20 m. This scenario is illustrated in Figure 3. The scanner is a passive instrument, requiring the radiance from the sun, therefore, operation were limited to day flights at solar elevation angles greater than 40 degrees. The operational scenario for the ABS NORDA Scanner and the entire ABS system will be refined by NAVOCEANO on an ongoing basis.

LASER SOUNDER

NORDA, in conjunction with the Naval Air Development Center (NADC), is assembling and testing the laser sounder. The laser sounder is currently installed on an NAVOCEANO P-3 aircraft to preform system verification and flight tests. Algorithms and computer software necessary to process laser sounder data are installed on NORDA's VAX 11/780 computer for testing and data processing.

The laser sounder uses a parallel processing computer architecture to control the transceiver, high density digital recorder, displays, and supporting input and output devices. Raw laser waveforms, containing sea surface and bottom return signals, are digitized, combined with navigational and timing information, and recorded for postprocessing. A read after write facility provides limited real time analysis of the data aboard the aircraft.

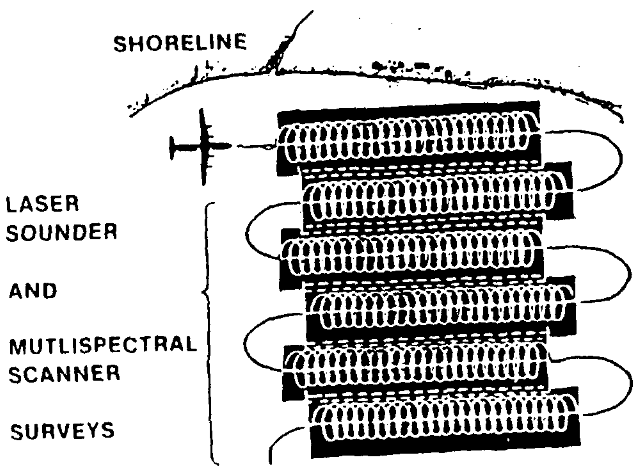

Fig. 3 - ABS OPERATIONAL SCENARIO.

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The laser sounder hardware included a 400 Hz cavity dumped Nd:YAG laser capable of producing pulses of 10 to 12 ns duration at 0.2 mJ average power. The beam divergence is set to maintain eye safety at operational altitude. The parallel processing system, based upon four micro-processors, provided the capability of handling up to 1000 soundings per second, and allowing room for future expansion. A pair of interlaced digitizers sampled the return laser waveforms at 2.5 ns intervals to 8 bit resolution.

The laser simultaneously generated blue-green (532 nm) and infrared (1054 nm) laser pulses, which were transmitted downward from the aircraft off a rotating mirror. From an altitude of 500 m the mirror generated an egg-shaped pattern, approximated by an ellipse, on the surface of the water that was 270 m wide with the mirror set at a 15° angle off nadir. Mirror rotation rate was adjustable up to 7.5 Hz to allow soundings in the aft scan to interlace and not overlay those places in the forward scan.

The infrared pulse did not penetrate the water. It was reflected back to the aircraft to provide accurate slant ranging to the water surface Approximately 97% of the blue-green pulse penetrated the water surface and undergoes scattering and absorption as it passed down through the water column. After reflecting off the bottom sediment, the signal passed back up through the water column to the airborne receiver. The difference in time between the surface return and the bottom return was the basis for determining water depth.

Navigational, system performance, and real time waveform information were displayed aboard the aircraft to facilitate the assessment of data quality and to assist the operator in identifying anomalies that require further investigation. The post-processing software accepted digitized waveforms, navigational, attitude, and timing data. The output was a digital record of depth and position for each laser sounding. The optimization of the software for extracting water depths from laser signals was based upon extensive research, taking into account the biases introduced by the electronics and the oceanographic environment.

TABLE 1 - ABS NORDA SCANNER SPECTRAL BANDS

ABS BAND	SPECTRAL RANGE
1	450 - 480 nm
2	480 - 520 nm
3	520 - 550 nm
4	550 - 600 nm
5	630 - 690 nm
6	760 - 900 nm
7	1.55 - 1.75 um
8	2.08 - 2.35 um
9	10.4 - 12.5 um

MULTISPECTRAL SCANNER

The multispectral scanner was the second sensor integrated into the ABS system. NOARL installed a nine channel scanner in the NAVOCEANO aircraft for testing with the laser sounder. This sensor was based upon a modified thematic mapper design. It was built for NOARL by the National Aeronautics and Space Administration, Earth Resources Laboratory.

The multispectral scanner provided full coverage of the survey area with one meter (pixel size) resolution. The laser sounder were operated simultaneously to facilitate depth calibration of the imagery data. Of the nine spectral bands (Table 1), the bands in the blue and green range provided maximum depth penetration. When flown at 500 m altitude, the swath width was nearly double the swath width of the laser sounder.

Operation of the multispectral scanner was limited to day flights only, because it is a passive sensor, requiring sunlight. Depths were determined from a reflectance model and compared with depths derived from the laser sounder data. A multiband algorithm[4] was used to minimize the difficulties encountered due to changes in bottom reflectance and water attenuation.

The multispectral hardware consisted of the scanner instrument, signal processor, recorder, video monitor, and power supply.

NAVIGATION SUBSYSTEM

A navigational data collection subsystem continually collected all pertinent aircraft position and attitude information from a GPS receiver and the P3-C Litton-72 inertial navigation system. This data was edited and transferred to the data collection system. The GPS receiver updates the position and time solution at 1-s intervals. To correlate each laser measurement with position every laser shot is time tagged with a 1-ms resolution clock reading. This clock is synchronized to the GPS receiver. Absolute position error of the GPS was about 25 m.

SUMMARY

The development of the ABS system was the first attempt to obtain bathymetric data meeting IHO standards using an airborne optical active/passive approach. The IHO standards for the scale of charts that the ABS would support (1:25000) require positioning and depth accuracies of 37.5 and 0.3 m, respectively. The data that was acquires by the system during the 1988 test flight was shown to have positioning errors of less than 40 m rms and depth accuracies of less than 1 m rms for both sensors.

The positioning accuracies will improve when the full complement of GPS satellites becomes operational. There were difficulties in separating the effects of positioning and depth errors. Errors in position combine with the bottom slope cause an increase in the depth error. Limited work is continuing to develop an analysis technique that will further segregate the two sources of depth errors.

When operational, a future development such as the ABS system will provide a relatively fast and inexpensive means of addressing the significant backlog in coastal survey requirements. The combination of the laser sounder and multispectral scanner provided a suite of sensors that can collect bathymetric information in clear waters during day or night operations to depths of 30 m.

ACKNOWLEDGEMENT

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